

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

Forename(s)

Candidate signature

I declare this is my own work.

INTERNATIONAL A-LEVEL CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen. Use pencil only for drawing.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
TOTAL	



Answer **all** questions in the spaces provided.

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0 1

This question is about sodium fluoride.

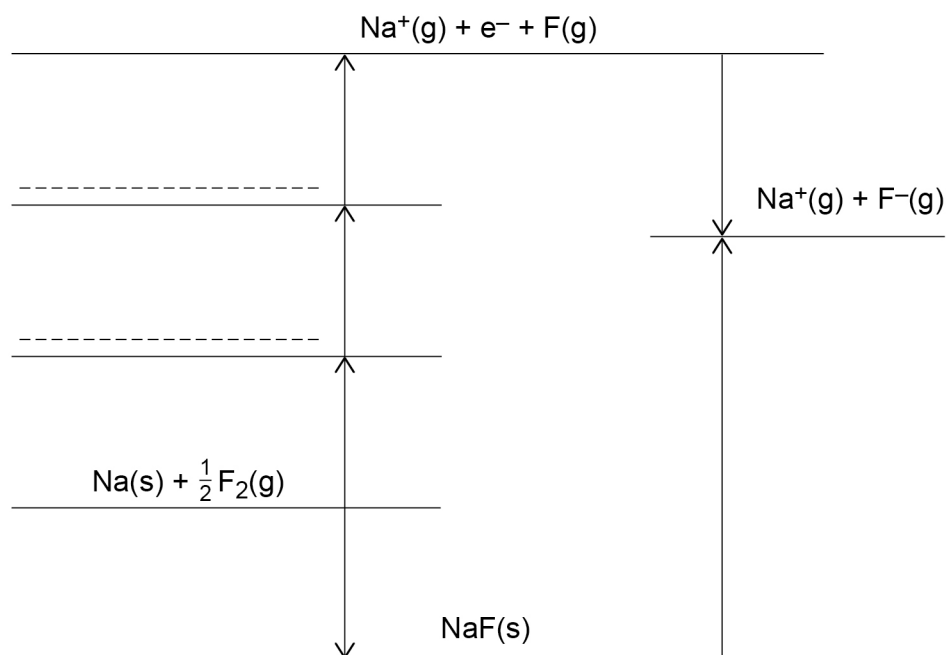
0 1 . 1

Figure 1 shows an incomplete Born–Haber cycle for the formation of sodium fluoride.

Complete **Figure 1** by writing the formulas, including state symbols, of the appropriate species on the two dotted lines.

[2 marks]

Figure 1



0 1 . 2 Table 1 shows some thermodynamic data.

Table 1

	$\Delta H^\ominus / \text{kJ mol}^{-1}$
$\text{Na(s)} \rightarrow \text{Na(g)}$	+109
$\text{Na(g)} \rightarrow \text{Na}^+(\text{g}) + \text{e}^-$	+494
$\text{F}_2(\text{g}) \rightarrow 2\text{F(g)}$	+158
$\text{F(g)} + \text{e}^- \rightarrow \text{F}^-(\text{g})$	-348
$\text{NaF(s)} \rightarrow \text{Na}^+(\text{g}) + \text{F}^-(\text{g})$	+902

Use **Figure 1** and the values given in **Table 1** to calculate a value for the enthalpy of formation of sodium fluoride.

[2 marks]

Enthalpy of formation _____ kJ mol^{-1}

0 1 . 3 State why the theoretical enthalpy of lattice dissociation for sodium fluoride in a data book is less endothermic than the experimental value calculated using a Born–Haber cycle.

[1 mark]

Turn over ►



0 1 . 4

How does the value for the enthalpy of lattice dissociation for sodium chloride compare with the value for the enthalpy of lattice dissociation for sodium fluoride?

[1 mark]

Tick (✓) **one** box.

The value for sodium chloride is more endothermic.

☐

The values for sodium chloride and for sodium fluoride are the same.

☐

The value for sodium chloride is less endothermic.

☐

0 1 . 5

An equation for the process that happens when sodium fluoride dissolves in water is shown.

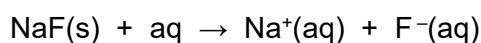


Table 2 shows some thermodynamic data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of lattice dissociation for NaF(s)	+902
Enthalpy of hydration for $\text{Na}^+(\text{g})$	−406
Enthalpy of hydration for $\text{F}^-(\text{g})$	−506

Use the data in **Table 2** to calculate the enthalpy of solution for sodium fluoride.

[2 marks]

Enthalpy of solution _____ kJ mol^{-1}



Turn over for the next question

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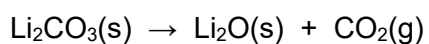
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ANSWER IN THE SPACES PROVIDED**

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0 2

Lithium carbonate decomposes as shown.



The Gibbs free-energy change, ΔG , varies with temperature as shown

$$\Delta G = \Delta H - T\Delta S$$

Table 3 shows how the value for ΔG for the decomposition of lithium carbonate varies with temperature.

Table 3

T / K	$\Delta G / \text{kJ mol}^{-1}$
300	177
600	128
900	80
1200	31
1500	-18

0 2 . 1

Use the data in **Table 3** and the grid on page 7 to plot a graph of ΔG (y-axis) against temperature.

[2 marks]

0 2 . 2

Use the gradient of your graph to deduce the entropy change (ΔS) for this reaction.

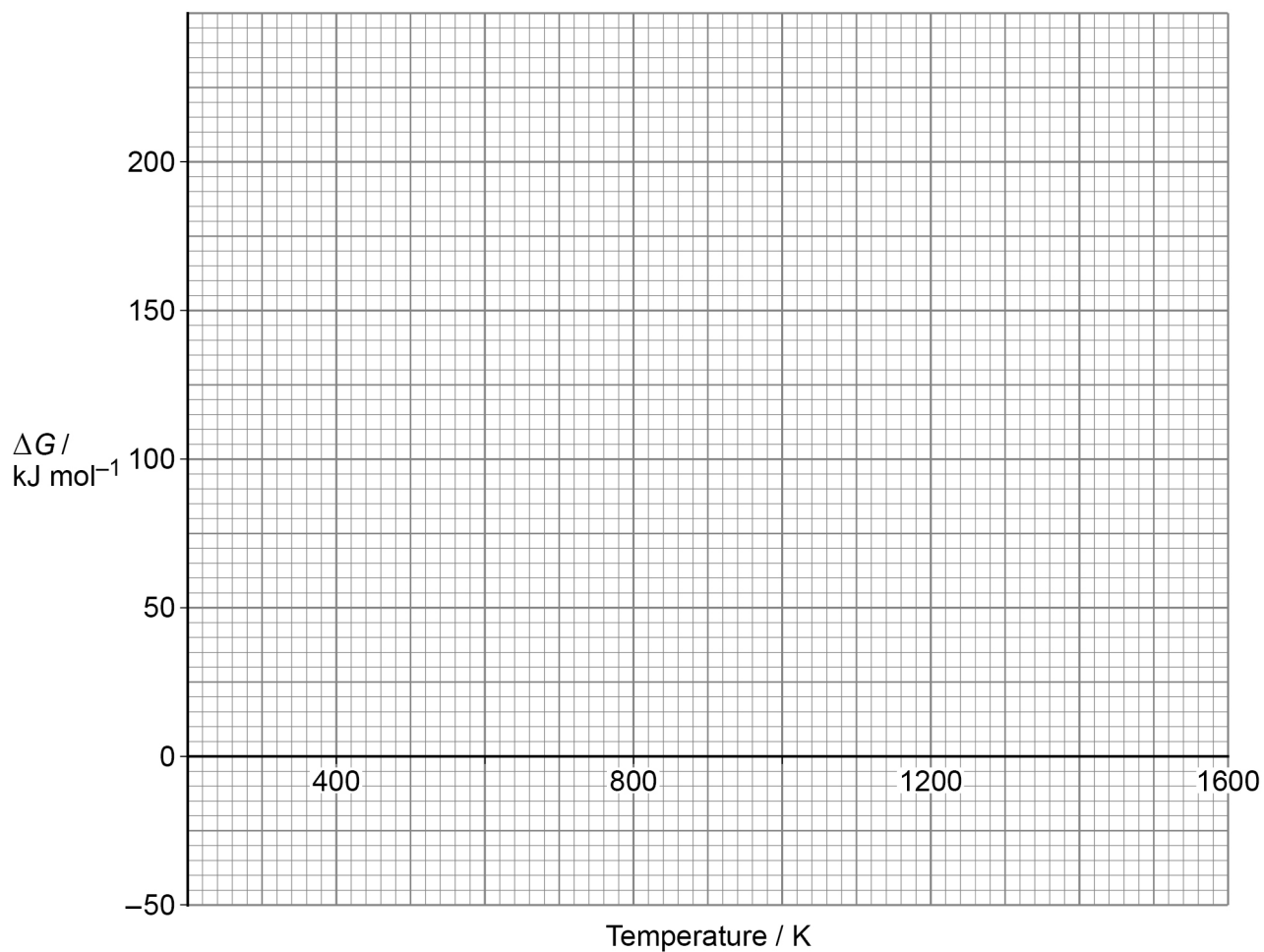
State the units.

[3 marks]

ΔS _____

Units _____





0 2 . 3

Use your graph to deduce the temperature, in K, at which the reaction becomes feasible.

[1 mark]

_____ K

6

Turn over for the next question

Turn over ►



0	3
---	---

This question is about the elements in Period 3 and their compounds.

0	3	.	1
---	---	---	---

Give **two** observations made when sodium reacts with oxygen.

Write an equation for this reaction.

[3 marks]

Observation 1 _____

Observation 2 _____

Equation

0	3	.	2
---	---	---	---

Draw the structure of the compound ($M_r = 267.0$) formed when aluminium reacts with chlorine.

Show each covalent bond as a line (—) and each co-ordinate bond as an arrow (→).

[2 marks]



0 3 . 3 Write an equation for the reaction of phosphorus(V) oxide with water.

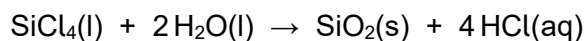
Draw the structure of the phosphorus-containing compound formed.

[2 marks]

Equation

Structure

0 3 . 4 A 0.750 g sample of silicon tetrachloride reacts with an excess of water to form an acidic solution.



Calculate the volume, in cm^3 , of $0.500 \text{ mol dm}^{-3}$ aqueous sodium hydroxide needed to neutralise the acidic solution formed.

[3 marks]

Volume _____ cm^3

Turn over ►



0 3 . 5 **Table 4** shows the melting points of silicon dioxide and silicon tetrachloride.

Table 4

	Melting point / K
Silicon dioxide	1986
Silicon tetrachloride	204

Explain, in terms of structure and bonding, why the melting points of silicon dioxide and silicon tetrachloride are different.

[4 marks]

14

Turn over for the next question

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0	4
---	---

This question is about hydrated ammonium iron(II) sulfate, $(\text{NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 \cdot x\text{H}_2\text{O}$ where x is a whole number.

0	4	.	1
---	---	---	---

A student determines the number of moles of water of crystallisation in hydrated ammonium iron(II) sulfate. The value of x can be calculated using the results from a titration of an acidified solution of ammonium iron(II) sulfate with potassium manganate(VII).

Method

- Dissolve 6.615 g of hydrated ammonium iron(II) sulfate in sulfuric acid and make the solution up to 250 cm^3
- Transfer a 25.0 cm^3 portion of this solution to a conical flask.
- Add $0.0150 \text{ mol dm}^{-3}$ potassium manganate(VII) solution from a burette until the mixture in the conical flask just becomes pink.
- Repeat the titration until concordant results are obtained.

The student calculates the mean titre of the potassium manganate(VII) solution to be 22.50 cm^3

Use the data to calculate the value of x in hydrated ammonium iron(II) sulfate.

M_r of $(\text{NH}_4)_2\text{SO}_4 \cdot \text{FeSO}_4 = 284.0$

[5 marks]

Value of x _____



0	4	.	2
---	---	---	---

State why the mixture in the conical flask becomes pink when the end point of the titration is reached.

[1 mark]

0	4	.	3
---	---	---	---

One reagent can be used to show that a solution of ammonium iron(II) sulfate contains both NH_4^+ ions and Fe^{2+} ions.

Identify this reagent.

Give the observation(s) that would be made with this reagent that shows the presence of each cation.

[3 marks]

Reagent _____

Observation to show the presence of NH_4^+ ions _____

Observation to show the presence of Fe^{2+} ions _____

9

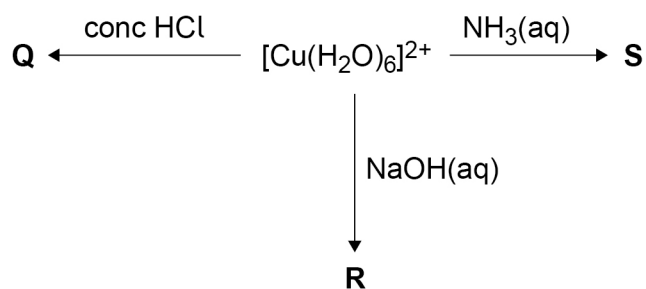
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0 5

Some reactions involving aqueous copper(II) complex ions are shown.

**0 5 . 1**

State the meaning of the term complex ion.

[1 mark]

0 5 . 2

Aqueous copper(II) ions react with an excess of concentrated hydrochloric acid to form a solution containing complex ion **Q**.

Write an equation for the reaction.

Give a reason why there is a colour change in this reaction.

[2 marks]

Equation

Reason



0 5 . 3 Aqueous copper(II) ions react with aqueous sodium hydroxide to form complex **R**.

State what would be observed.

Write an equation for the reaction.

[2 marks]

Observation _____

Equation _____

0 5 . 4 Aqueous copper(II) ions react with an excess of aqueous ammonia to form a solution containing complex ion **S**.

State what would be observed when aqueous ammonia is added dropwise, until in excess, to a solution containing aqueous copper(II) ions.

Write an equation for the overall reaction.

[3 marks]

Observations _____

Equation _____

8

Turn over for the next question

Turn over ►



0 6

This question is about transition metal complex ions.

0 6 . 1

An octahedral complex absorbs light with a wavelength (λ) of 535 nm because of d–d electron transitions.

The energy difference (ΔE) between the ground state and the excited state of the d electrons is

$$\Delta E = \frac{hc}{\lambda}$$

Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$

Speed of light, $c = 3.00 \times 10^8 \text{ m s}^{-1}$

Calculate the energy difference, in J, between the d orbitals.

Assume that the light is absorbed only in d–d electron transitions.

[2 marks]

Energy difference _____ J

0 6 . 2

State **two** changes that could be made to a transition metal ion in solution that would influence the ability of the transition metal ion to change from a higher to a lower oxidation state.

[2 marks]

1 _____

2 _____



0	6	.	3
---	---	---	---

Ethane-1,2-diamine ($\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$) can act as a bidentate ligand. When an excess of ethane-1,2-diamine is added to a solution containing $[\text{Co}(\text{NH}_3)_6]^{2+}$ ions, all the ammonia ligands are replaced.

Write an equation for this reaction.

Explain the chelate effect in terms of the entropy change and the enthalpy change in this reaction.

[5 marks]

Equation

Explanation

Question 6 continues on the next page

Turn over ►



0 6 . 4

The complex ion $[\text{Co}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)_2]^{2-}$ exists in three isomeric forms. It exhibits both *cis-trans* and optical isomerism.

Draw the structure of **one** of the optical isomers.

[1 mark]

10

Turn over for the next question

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0 7

This question is about electrochemical cells.

Table 5 shows some standard electrode potential data.

Table 5

Electrode half-equation	$E^\ominus / \text{V}$
$2\text{BrO}_3^-(\text{aq}) + 12\text{H}^+(\text{aq}) + 10\text{e}^- \rightarrow \text{Br}_2(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$	+1.52
$\text{Br}_2(\text{aq}) + 2\text{e}^- \rightarrow 2\text{Br}^-(\text{aq})$	+1.07
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.44

0 7 . 1

Identify the species in **Table 5** that can oxidise iron to iron(II) ions with no further reaction.

Deduce an overall equation for this reaction.

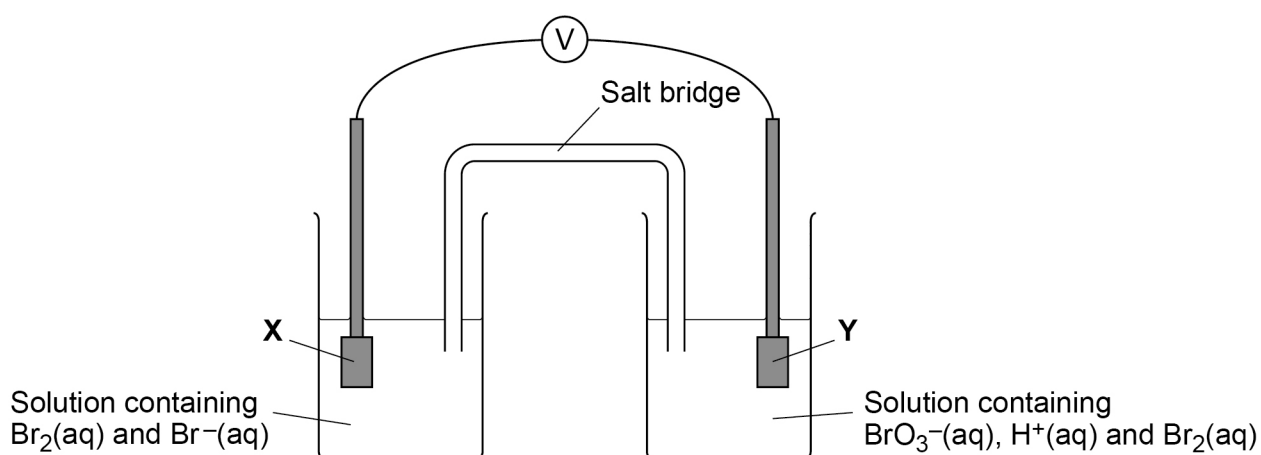
[2 marks]

Species _____

Equation _____

Figure 2 shows an electrochemical cell.

Figure 2



0 7 . 2 Use data from **Table 5** to calculate the EMF of the cell in **Figure 2**.

Deduce the overall redox equation for the reaction.

[3 marks]

EMF _____

Equation _____

0 7 . 3 State why a salt bridge is needed.

Identify a salt to use in the salt bridge for this electrochemical cell.

[2 marks]

Why salt bridge is needed _____

Identity of salt _____

0 7 . 4 Identify a material used for electrodes **X** and **Y** in **Figure 2**.

Give a reason for using this material.

[2 marks]

Material _____

Reason _____

0 7 . 5 What is the effect on the EMF of the cell if the surface area of both electrodes is doubled?

[1 mark]

Tick (✓) **one** box.

EMF is increased by a factor of 4

☐

EMF is increased by a factor of 2

☐

EMF is unchanged.

☐

10

Turn over ►



0	8
---	---

This question is about pH.

0	8	.	1
---	---	---	---

Define the term pH.

[1 mark]

0	8	.	2
---	---	---	---

A 20.0 cm³ sample of 0.115 mol dm⁻³ hydrochloric acid is diluted with deionised water to form 145 cm³ of solution.

Calculate the pH of the solution formed.

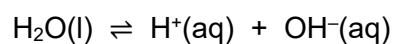
Give your answer to 2 decimal places.

[3 marks]

pH _____



0 8 . 3 Water dissociates as shown.



At 45 °C, the ionic product of water (K_w) has a value of $4.02 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$

Calculate the pH of water at 45 °C

Give your answer to 2 decimal places.

[2 marks]

pH _____

0 8 . 4 Calculate the pH of $0.175 \text{ mol dm}^{-3}$ aqueous butanoic acid ($\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$) at 25 °C

For butanoic acid at 25 °C, the acid dissociation constant, $K_a = 1.51 \times 10^{-5} \text{ mol dm}^{-3}$

Give your answer to 2 decimal places.

[3 marks]

pH _____

Turn over ►



0 8 . 5

Aqueous sodium hydroxide is added to 25.0 cm³ of aqueous butanoic acid (CH₃CH₂CH₂COOH) in a titration.

Figure 3 shows how the pH of the solution changes.

Figure 3

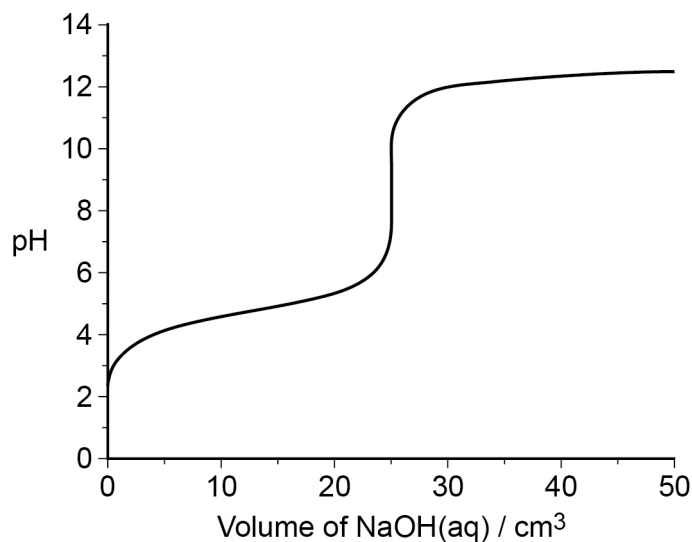


Table 6 shows the pH ranges of some indicators.

Table 6

Indicator	pH range
Thymol blue	1.2–2.8
Methyl orange	3.1–4.4
Thymolphthalein	9.3–10.5
Indigo carmine	11.6–14.0

Use **Table 6** to identify the most suitable indicator for this titration.

[1 mark]



0	8	.	6
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Butanoic acid ($\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$) and sodium butanoate ($\text{CH}_3\text{CH}_2\text{CH}_2\text{COONa}$) are mixed at 25°C to form a buffer solution with $\text{pH} = 4.50$

Calculate the mass, in grams, of sodium butanoate that should be added to 50.0 cm^3 of 0.175 mol dm^{-3} aqueous butanoic acid to prepare this buffer solution.

For butanoic acid at 25°C , the acid dissociation constant, $K_a = 1.51 \times 10^{-5}\text{ mol dm}^{-3}$

[5 marks]

Mass of sodium butanoate _____ g

15

END OF QUESTIONS



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